

# EXEMPLAR SOLUTIONS PHYSICS

Chapter 5: Magnetism and Matter

Class  
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## Chapter 5- Magnetism and Matter

### Multiple Choice Questions I

**5.1. A toroid of  $n$  turns, mean radius  $R$  and cross-sectional radius  $a$  carries current  $I$ . It is placed on a horizontal table taken as  $x$ - $y$  plane. Its magnetic moment  $m$**

**a) is non-zero and points in the  $z$ -direction by symmetry**

$$m = m\hat{\phi}$$

**b) points along the axis of the toroid**

**c) is zero, otherwise there would be a field falling as  $1/r^3$  at large distances outside the toroid**

**d) is pointing radially outwards**

**Answer:**

**c) is zero, otherwise there would be a field falling as  $1/r^3$  at large distances outside the toroid**

**5.2. The magnetic field of the earth can be modelled by that of a point dipole placed at the centre of the earth. The dipole axis makes an angle of  $11.3^\circ$  with the axis of the earth. At Mumbai, declination is nearly zero. Then,**

**a) the declination varies between  $11.3^\circ$  W to  $11.3^\circ$  E**

**b) the least declination is  $0^\circ$**

**c) the plane defined by dipole axis and the earth axis passes through Greenwich**

**d) declination average over the earth must be always negative**

**Answer:**

**a) the declination varies between  $11.3^\circ$  W to  $11.3^\circ$  E**

**5.3. In a permanent magnet at room temperature**

**a) magnetic moment of each molecule is zero**

**b) the individual molecules have non-zero magnetic moment which are all perfectly aligned**

**c) domains are partially aligned**

**d) domains are all perfectly aligned**

**Answer:**

**d) domains are all perfectly aligned**

**5.4. Consider the two idealized systems: i) a parallel plate capacitor with large plates and small separation and ii) a long solenoid of length  $L \gg R$ , radius of cross-section. In i)  $E$  is ideally treated as a constant between plates and zero outside. In ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below:**

**a) case (i) contradicts Gauss's law for electrostatic fields**

**b) case (ii) contradicts Gauss's law for magnetic fields**

$$\oint \vec{E} \cdot d\vec{l} = 0$$

**c) case (i) agrees with**

$$\oint \vec{H} \cdot d\vec{l} = I_{em}$$

**d) case (ii) contradicts**

**Answer:**

**b) case (ii) contradicts Gauss's law for magnetic fields**

**5.5. A paramagnetic sample shows a net magnetisation of  $8 \text{ Am}^{-1}$  when placed in an external magnetic field**



of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2T at a temperature of 16K, the magnetisation will be

- a)  $32/3 \text{ Am}^{-1}$
- b)  $2/3 \text{ Am}^{-1}$
- c)  $6 \text{ Am}^{-1}$
- d)  $2.4 \text{ Am}^{-1}$

Answer:

- b)  $2/3 \text{ Am}^{-1}$

## Multiple Choice Questions II

5.6. S is the surface of a lump of magnetic material

- a) lines of B are necessarily continuous across S
- b) some lines of B must be discontinuous across S
- c) lines of H are necessarily continuous across S
- d) lines of H cannot all be continuous across S

Answer:

- a) lines of B are necessarily continuous across S
- d) lines of H cannot all be continuous across S

5.7. The primary origin(s) of magnetism lies in

- a) atomic currents
- b) Pauli exclusion principle
- c) polar nature of molecules
- d) intrinsic spin of electron

Answer:

- a) atomic currents
- d) intrinsic spin of electron

5.8. A long solenoid has 1000 turns per meter and carries a current of 1 A. It has a soft iron core of  $\mu_r = 1000$ . The core is heated beyond the Curie temperature  $T_c$

- a) the H field in the solenoid is unchanged but the B field decreases drastically
- b) the H and B fields in the solenoid are nearly unchanged
- c) the magnetisation in the core reverses direction
- d) the magnetisation in the core diminishes by a factor of about 108

Answer:

- a) the H field in the solenoid is unchanged but the B field decreases drastically
- d) the magnetisation in the core diminishes by a factor of about 108

5.9. Essential difference between electrostatic shielding by a conducting shell and magneto static shielding is due to

- a) electrostatic field lines can end on charges and conductors have free charges
- b) lines of B can also end but conductors cannot end them
- c) lines of B cannot end on any material and perfect shielding is not possible
- d) shells of high permeability materials can be used to divert lines of B from the interior region

Answer:

- a) electrostatic field lines can end on charges and conductors have free charges
- c) lines of B cannot end on any material and perfect shielding is not possible
- d) shells of high permeability materials can be used to divert lines of B from the interior region

**5.10. Let the magnetic field on the earth be modelled by that of a point magnetic dipole at the centre of the earth. The angle of dip at a point on the geographical equator**

- a) is always zero
- b) can be zero at specific points
- c) can be positive or negative
- d) is bounded

**Answer:**

- b) can be zero at specific points
- c) can be positive or negative
- d) is bounded

### **Very Short Answers**

**5.11. A proton has spin and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?**

**Answer:**

The comparison between the spinning of a proton and an electron is done by comparing their magnetic dipole moment which is given as

$$\mu_p = eh/4\pi m_p$$

$$\mu_e = eh/4\pi m_e$$

$$\mu_p/\mu_e = m_e/m_p = 1/1837 \gg 1$$

$$\mu_p \ll \mu_e$$

**5.12. A permanent magnet in the shape of a thin cylinder of length 10 cm has  $M = 10^6$  A/m. Calculate the magnetisation current  $I_M$ .**

**Answer:**

$$\text{Intensity of magnetisation} = 10^6 \text{ A/m}$$

$$\text{Length, } l = 0.1 \text{ m}$$

$$M = I_M/l$$

$$I_M = Ml = 10^5 \text{ A}$$

**5.13. Explain quantitatively the order of magnitude difference between the diamagnetic susceptibility of  $N_2$  and Cu.**

**Answer:**

$$\text{Density of nitrogen} = 28 \text{ g/} 22400 \text{ cc}$$

$$\text{Density of copper} = 8 \text{ g/} 22400 \text{ cc}$$

$$\text{Ratio of densities} = 16 \times 10^{-4}$$

$$\text{Diamagnetic susceptibility} = \text{density of nitrogen/density of copper} = 1.6 \times 10^{-4}$$

**5.14. From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism, and ferromagnetism.**

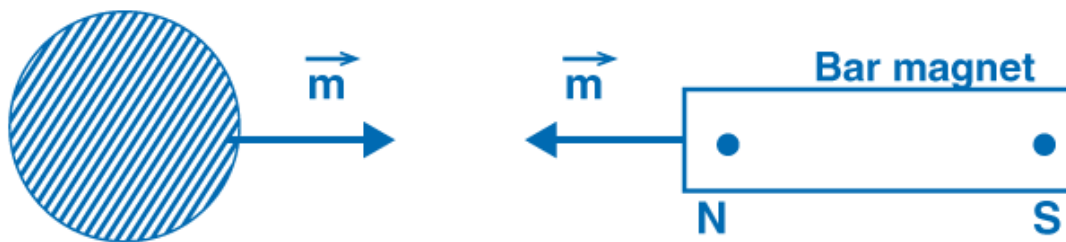
**Answer:**

The temperature dependence of susceptibility for a diamagnetism is not much affected by the temperature.

The temperature dependence of susceptibility for a paramagnetism and ferromagnetism is affected by the temperature that is as the temperature rises, the magnetic moments get disturbed.

**5.15. A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. i) In which direction will it move? ii) What will be the direction of its magnetic moment?**

**Answer:**



- i) The superconducting material will move away from the bar magnet.
- ii) The direction of the magnetic moment will be from left to right.

### Short Answers

**5.16. Verify the Gauss's law for magnetic field of a point dipole of dipole moment  $m$  at the origin for the surface which is a sphere of radius  $R$ .**

**Answer:**



P is the point at a distance  $r$  from O and OP, then magnetic field is given as:

$$B = \frac{\mu_0}{4\pi} \frac{2M \cos \theta}{r^3} \hat{r}$$

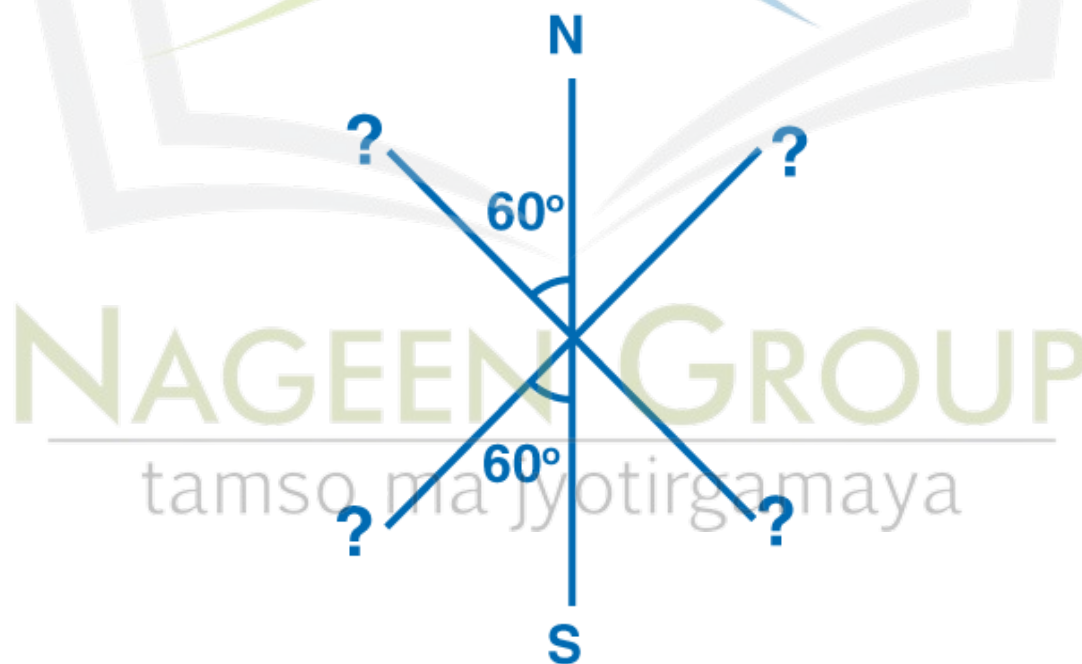
$dS$  is the elementary area of the surface  $P$ , then  
 $dS = r^2 (\sin \theta \, d\theta \, d\phi)$

$$\oint B \cdot dS = \oint \frac{\mu_0}{4\pi} \frac{2M \cos \theta}{r^3} \hat{r} (r^2 \sin \theta \, d\theta \, d\phi)$$

Solving the above we get,

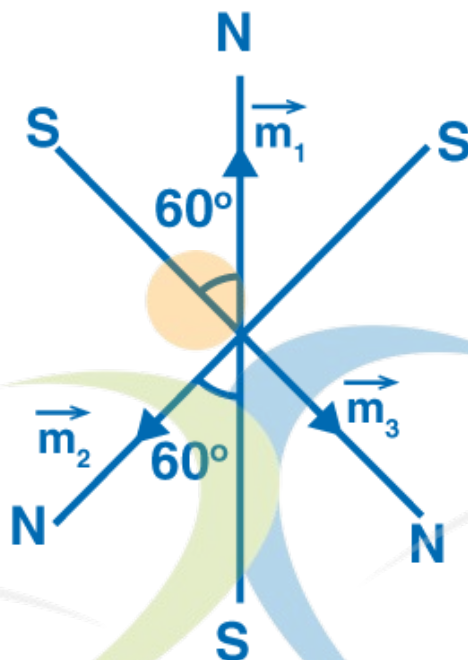
$$\oint B \cdot dS = -\frac{\mu_0}{4\pi} \frac{M}{2r} [1 - 1] = 0$$

**5.17. Three identical bar magnets are riveted together at centre in the same plane as shown in the figure. This system is placed at rest in a slowly varying magnetic field. It is found that the system of magnets does not show any motion. The north-south poles of one magnet is shown in the figure. Determine the poles of the remaining two.**



**Answer:**





The system will have a net torque and the net force equal to zero as the system is in equilibrium.

**5.18. Suppose we want to verify the analogy between electrostatic and magnetostatic by an explicit experiment. Consider the motion of i) electric dipole  $p$  in an electrostatic field  $E$  and ii) magnetic dipole  $m$  in a magnetic field  $B$ . Write down a set of conditions on  $E$ ,  $B$ ,  $p$ ,  $m$  so that the two motion are verified to be identical.**

**Answer:**

$$pE \sin \theta = \mu B \sin \theta$$

$$pE = \mu B$$

$$E = cB$$

$$pcB = \mu B$$

$$p = \mu/c$$

**5.19. A bar magnet of magnetic moment  $m$  and moment of inertia  $I$  is cut into two equal pieces, perpendicular to length. Let  $T$  be the period of oscillations of the original magnet about an axis through the mid point, perpendicular to length, in a magnetic field  $B$ . What would be the similar period  $T'$  for each piece?**

**Answer:**

$T$  is the time period

$I$  is the moment of inertia

$m$  is the mass of magnet

$B$  is the magnetic field

$$T = 2\pi\sqrt{I/MB}$$

Magnetic dipole moment  $M' = M/2$

Time period is given as  $T' = T/2$

5.20. Use i) the Ampere's law for  $H$  and ii) continuity of lines of  $B$ , to conclude that inside a bar magnet a) lines of  $H$  run from the N pole to S pole, while b) lines of  $B$  must run from the S pole to N pole.

Answer:



C is the amperian loop which is given as

$$\int_Q^P \vec{H} \cdot d\vec{l} = \int_Q^P \frac{\vec{B}}{\mu_0} \cdot d\vec{l}$$

$\vec{H}$  and  $d\vec{l}$

Solving the above equation we get the angle between  $\vec{H}$  and  $d\vec{l}$  is more than  $90^\circ$  so that  $\cos \theta$  is negative.

more than  $90^\circ$  so that  $\cos \theta$  is

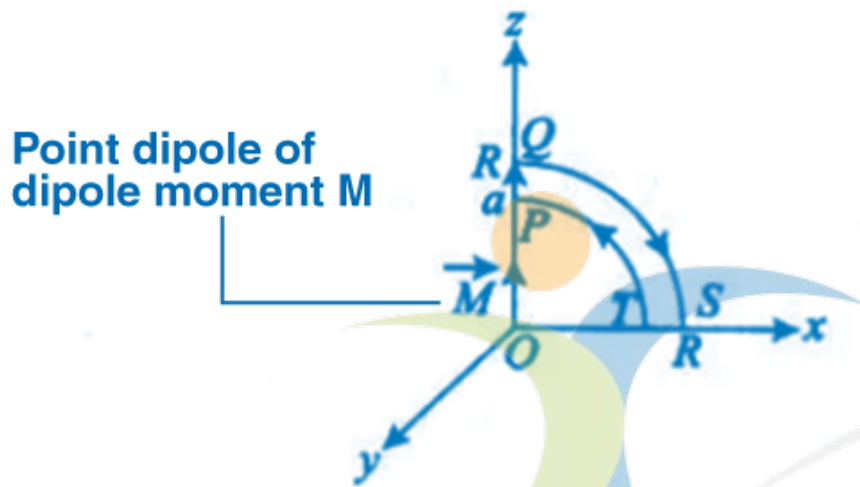
**Long Answers**

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5.21. Verify the Ampere's law for magnetic field of a point dipole of dipole moment  $m = m\hat{k}$ . Take C as the closed curve running clockwise along i) the z-axis from  $z = a > 0$  to  $z = R$ ; ii) along the quarter circle of radius R and centre at the origin, in the first quadrant of x-z plane; iii) along the x-axis from  $x = R$  to  $x = a$  and iv) along the quarter circle of radius a and centre at the origin in the first quadrant of x-z plane.

Answer:

a)



Along z-axis, magnetic field =  $\mu_0 M / 4\pi (1/a^2 - 1/R^2)$

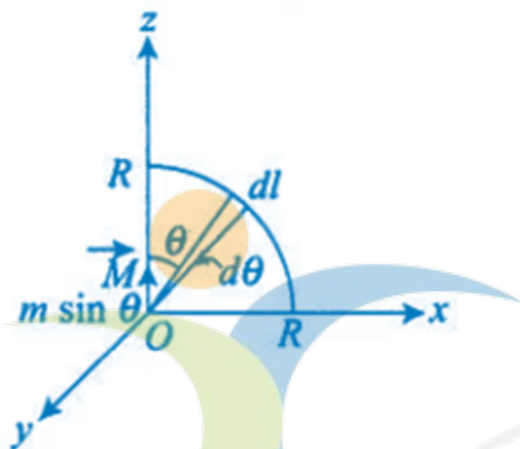
b)  
Magnetic field at point A on the circular arc is =  $\mu_0 m / 4\pi R^2$

c)



The magnetic moment is 0

d)



The magnetic moment is 0

5.22. What are the dimensions of  $\chi$ , the magnetic susceptibility? Consider an H-atom. Guess an expression for  $\chi$ , upto a constant by constructing a quantity of dimensions of  $\chi$ , out of parameters of the atom:  $e$ ,  $m$ ,  $v$ ,  $R$  and  $\mu_0$ . Here,  $m$  is the electronic mass,  $v$  is electronic velocity,  $R$  is Bohr radius. Estimate the number so obtained and compare with the value of  $|\chi|$  equivalent to  $10^{-5}$  for many solid materials.

**Answer:**

$\chi_m = I/H = \text{intensity of magnetisation/magnetising force}$

$\chi$  is dimensionless as  $I$  and  $H$  has same units

$\chi = 10^{-4}$

5.23. Assume the dipole model for earth's magnetic field  $B$  which is given by  $B_v = \text{vertical component of magnetic field} = \mu_0/4\pi \cdot 2m \cos \theta/r^3$ ,  $B_h = \text{horizontal component of magnetic field} = \mu_0/4\pi \cdot 2m \sin \theta/r^3$ ,  $\theta = 90^\circ$  latitude as measured from magnetic equator. Find loci of points for which i)  $|B|$  is minimum ii) dip angle is zero, and iii) dip angle is  $\pm 45^\circ$ .

**Answer:**

a)  $|B|$  is minimum at the magnetic equator.

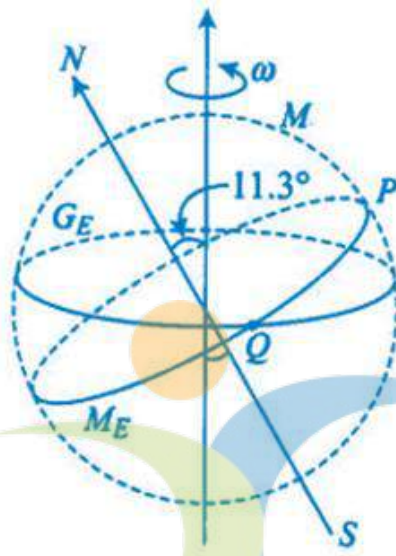
b) Angle of dip is zero when  $\theta = \pi/2$

c) When dip angle is  $\pm 45^\circ$   $\theta = \tan^{-1}$  is the locus.

5.24. Consider the plane  $S$  formed by the dipole axis and the axis of earth. Let  $P$  be point on the magnetic equator and in  $S$ . Let  $Q$  be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angle at  $P$  and  $Q$ .

**Answer:**





Point P is in the plane, S is in the north and the declination is zero.

The declination is zero for point P as the point lies in the plane S formed by the dipole axis and the axis of the earth

The angle of dip is zero for point Q as the point Q lies on the magnetic equator and the angle of declination is  $11.3^\circ$ .

**5.25. There are two current carrying planar coils made each from identical wires of length  $L$ .  $C_1$  is circular and  $C_2$  is square. They are so constructed that they have same frequency of oscillation when they are placed in the same uniform  $B$  and carry the same current. Find  $a$  in terms of  $R$ .**

**Answer:**

$C_1$  is the circular coil with radius  $R$ , length  $L$ , and no. of turns per unit length  $n_1 = L/2\pi R$

$C_2$  is the square with side  $a$ , perimeter  $L$ , and no. of turns per unit length  $n_2 = L/4a$

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Magnetic moment of  $C_1 = m_1 = n_1 i A_1$

Magnetic moment of  $C_2 = m_2 = n_2 i A_2$

$$m_1 = LiR/2$$

$$m_2 = Lia/4$$

Moment of inertia of  $C_1 = I_1 = MR^2/2$

Moment of inertia of  $C_2 = Ma^2/12$

Solving the above, we get,  $a = 3R$

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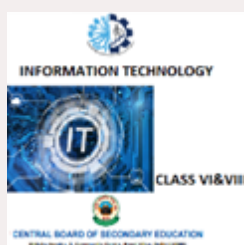
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Marketing/Commercial Application



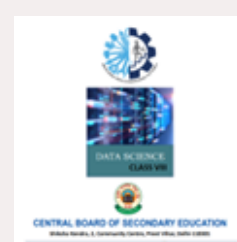
Mass Media - Being Media Literate



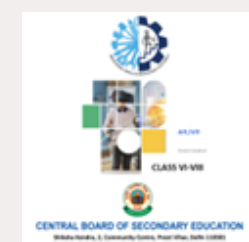
Travel & Tourism



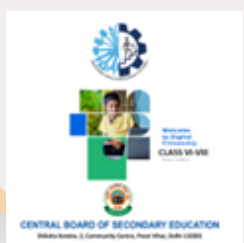
Coding



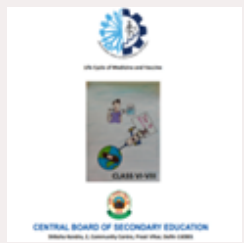
Data Science (Class VIII only)



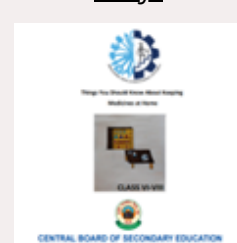
Augmented Reality / Virtual Reality



Digital Citizenship



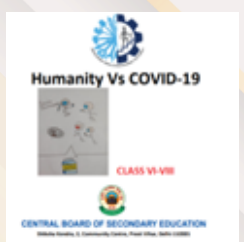
Life Cycle of Medicine & Vaccine



Things you should know about keeping Medicines at home



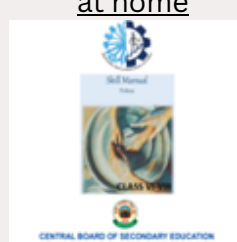
What to do when Doctor is not around



Humanity & Covid-19



Blue Pottery



Pottery



Block Printing



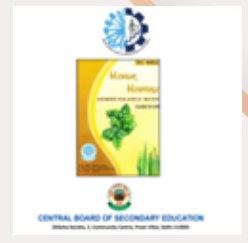
Food



Food Preservation



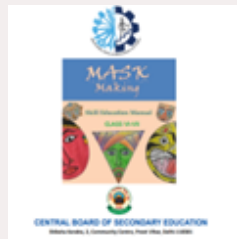
Baking



Herbal Heritage



Khadi



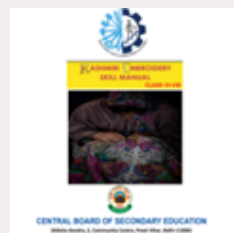
Mask Making



Mass Media



Making of a Graphic Novel



Kashmiri Embroidery



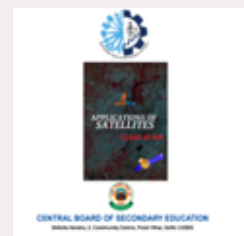
Embroidery



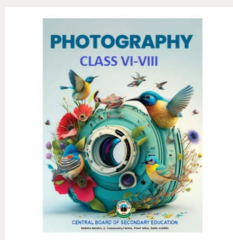
Rockets



Satellites

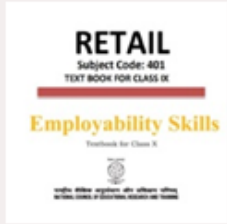


Application of Satellites

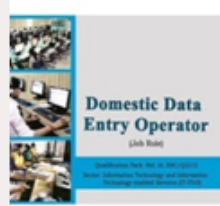


Photography

# SKILL SUBJECTS AT SECONDARY LEVEL (CLASSES IX – X)



Retail



Information Technology



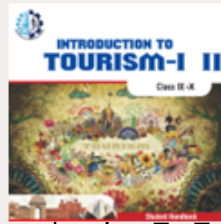
Security



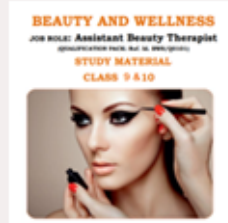
Automotive



Introduction To Financial Markets



Introduction To Tourism



Beauty & Wellness



Agriculture



Food Production



Front Office Operations



Banking & Insurance



Marketing & Sales



Health Care



Apparel



Multi Media



Multi Skill Foundation Course



Artificial Intelligence



Physical Activity Trainer



Data Science



Electronics & Hardware (NEW)



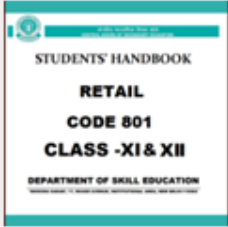
Foundation Skills For Sciences (Pharmaceutical & Biotechnology)(NEW)



Design Thinking & Innovation (NEW)



# SKILL SUBJECTS AT SR. SEC. LEVEL (CLASSES XI – XII)



Retail



Information Technology



Web Application



Automotive



Financial Markets Management



Tourism



Beauty & Wellness



Agriculture



Food Production



Front Office Operations



Banking



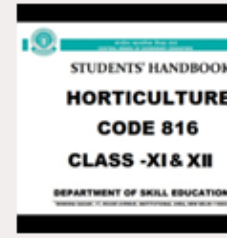
Marketing



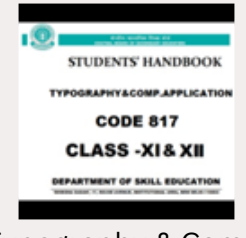
Health Care



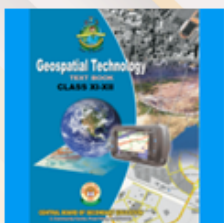
Insurance



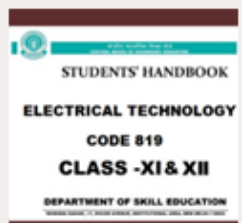
Horticulture



Typography & Comp.  
Application



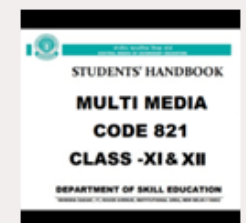
Geospatial Technology



Electrical Technology



Electronic Technology



Multi-Media

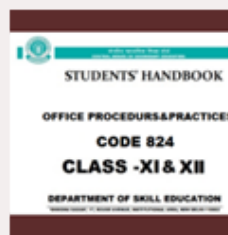




Taxation



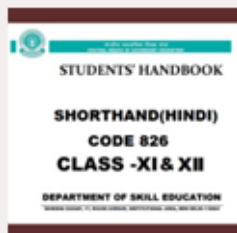
Cost Accounting



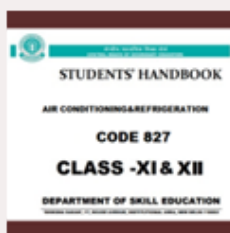
Office Procedures & Practices



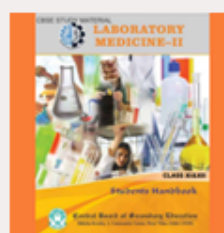
Shorthand (English)



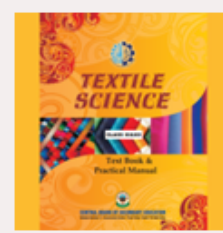
Shorthand (Hindi)



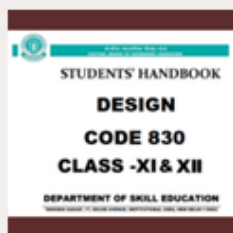
Air-Conditioning & Refrigeration



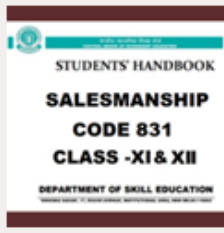
Medical Diagnostics



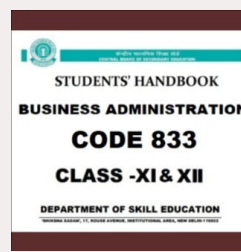
Textile Design



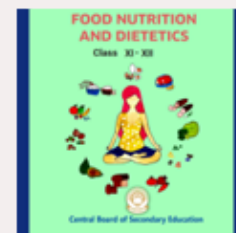
Design



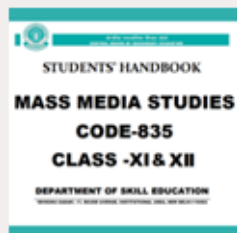
Salesmanship



Business Administration



Food Nutrition & Dietetics



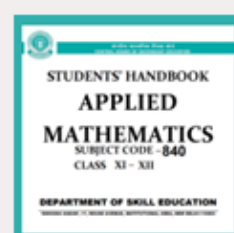
Mass Media Studies



Library & Information Science



Fashion Studies



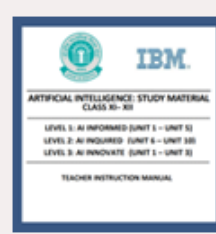
Applied Mathematics



Yoga



Early Childhood Care & Education



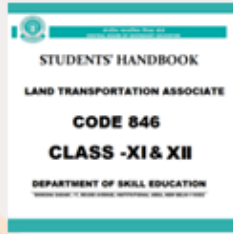
Artificial Intelligence



Data Science



Physical Activity Trainer(new)



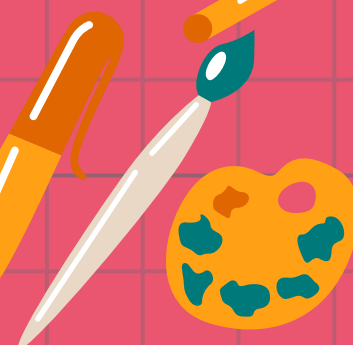
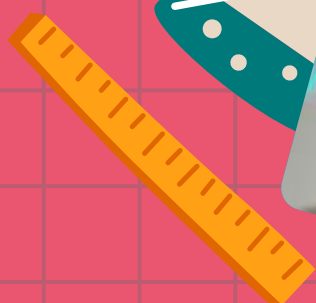
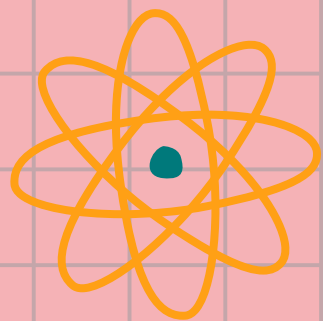
Land Transportation Associate (NEW)



Electronics & Hardware (NEW)



Design Thinking & Innovation (NEW)



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